Exploration risk evaluation through UASA techniques

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The evaluation of the exploration risk in the oil industry is a fundamental component of the decision process related to permit acquisition, potential trap selection and exploratory drilling.

Many different studies are exploited in order to get the best possible description of the geometry of the potential hydrocarbon traps and to evaluate the possible quantities of hydrocarbons (gas and oil) trapped into them.

The two basic components of the exploratory risk, trap position and shape (geometry) and trapped hydrocarbon quantities (fluid), are affected by many sources of uncertainty, which have been addressed using different UASA approaches by many authors.

However, these two sources of uncertainty have not been compounded in a single coherent UASA approach, but they have been addressed separately.

In this paper a new methodology is proposed that is able to handle both "geometric" and "fluid" uncertainty.

A well established approach to evaluate "geometric" uncertainty is based on the use of geostatistical techniques, that allow to produce a number of possible realizations of the trap geometry (position in space and shape), all compatible with available data.

On the other hand a Montecarlo based methodology has been proposed in order to evaluate the "fluid" uncertainty, i.e. the possible quantities of oil and gas that were generated in a basin and that migrated from the hydrocarbon source location to each single trap.

In both cases we may emphasize two types of uncertainty: interpretative and parametric.

Interpretative uncertainty is related to the fact that hydrocarbon exploration is based on the use of indirect measurements, which are available by means of geophysical campaigns or surface analogues. Only in few locations (those of the drilled wells) it is possible to get direct measurements, which are less uncertain than the indirect ones.

It is therefore necessary that an expert (a geologist) interprets all available data, to extract from indirect measurements (like acquired seismic data), the ones that allow, for example, to describe the earth in the area of study, i.e. to build a model of rock layers geometries and properties (porosity, seismic velocity, …).

It can happen that different experts suggest different interpretations, or alternative models, or that available data is not sufficient to decide among different models.

This "ambiguity" is a major source of uncertainty and has to be taken into account by introducing the concept of different interpretative "scenarios". In practice each scenario must be treated independently. The (possibly weighted) combination of them allows to obtain a better picture of the total risk.

Parametric uncertainty is related to the incomplete knowledge of the basin and of the processes that lead to the generation and expulsion of hydrocarbons during its evolution.

Parametric uncertainty is handled with classic Montecarlo approaches, improved by appropriate sampling techniques and computation of sensitivity indices in order to better understand the role of each parameter in the final result (hydrocarbon accumulation) and possibly to shrink uncertainty analysis to a reduced set of critical parameters.

The workflow used for the evaluation of the trap geometry can be represented, in a simplified way, as: seismic data acquisition and processing, seismic time interpretation, seismic velocity study, seismic time to depth conversion, calibration to wells depths.

The uncertainty approach assumes that the uncertainty of the seismic data is negligible (compared to the others), seismic time interpretation may produce different time model scenarios, seismic velocity is a great source of uncertainty, well depths are almost certain.

Therefore the methodology used to evaluate the depth uncertainty of all the layers, consists in producing a number of possible alternative seismic velocity fields (using geostatistical methods) and in depth-converting each interpreted seismic time model with each simulated velocity. This produces a number of possible depth models, around a reference one (or better: around several reference depth models, one for each time model scenario).

After that, each model has to be filled with all the properties (porosity, permeability, thermal conductivity, …) that are necessary to model hydrocarbon generation and accumulation.

Hydrocarbon content computation is strictly related to trap geometry evaluation. In order to assess the hydrocarbon filling of a trap it is necessary to model all the geological, physical and chemical processes that have brought to hydrocarbon accumulation.

A simplified workflow of these Petroleum System Modelling (PSM) steps is the following: structural modelling of the geologic evolution of the basin under study, modelling of the history of pressure and temperature regimes, modelling of the history of generation and expulsion of hydrocarbons from the source rock, and of the history of migration up to each trap in the basin.

It is quite clear that the geometry has an influence on each PSM step and that the "geometric" uncertainty will play a major role also into the "fluid" uncertainty.

This paper introduces a methodology to address simultaneously both sources of uncertainty. In practice it is shown that it is possible to take into account the uncertainty of :

a) some of the geometric features of the basin depth model;
b) heat flow history;
c) pressure and temperature scenarios;
d) generation and expulsion parameters;
e) hydrocarbon migration parameters;
f) trap filling and retaining parameters.

Whereas the uncertainty associated with "maps" is handled using a geostatistical approach, parameters are randomised using a Montecarlo-like technique.

Sensitivity analysis methods allow to clarify the role of each uncertain "variable" (map, parameter or scenario), to discard non valid combinations of variables, to possibly reduce the number of runs necessary to perform the final uncertainty analysis.

As some data (absence of hydrocarbons, gas and oil quantities, …) is available through previously drilled wells in the area, a calibration phase is performed, to accept only the simulations that fulfil known data. Moreover, updated probability distributions for each parameter are obtained (via Montecarlo filtering technique), which can be used in the final uncertainty run.

The discarded runs, after the calibration filtering, can be analysed to understand the reasons of their being "wrong", gaining more insight into the petroleum system model behaviour.

This methodology is described through an application to a real data set. For each trap in the basin, the probability (expressed by histograms) of hydrocarbon filling is computed.

The most interesting result is the ability to compare the "filling" probability of different traps, which enables a sound evaluation of the most promising ones.